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E7.6-10.106

CR-146039

(E76-10106) MULTIPLE RESOURCE EVALUATION OF REGION 2, US FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA Quarterly Progress Report, 1 Sep. - 30 Nov. 1975 (Colorado Univ.) 31 p HC $4.00 CSCL 08E G3/43

N76-16529

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MULTIPLE RESOURCE EVALUATION OF REGION 2 U.S. FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA

PAULA V. KREBS and STAFF
Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80302

In cooperation with

Roger M. Hoffer and Staff
Laboratory for Applications of Remote Sensing
Purdue University
1220 Potter Drive
West Lafayette, Indiana 47907

and

Region 2 U.S. Forest Service, U.S.D.A.
P. O. Box 25127
Denver, Colorado 80225

November 1975, QUARTERLY PROGRESS REPORT
For Period September 1 - November 30, 1975

NASA CONTRACT NAS 5-20948

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

23760

1. Report No. Type II, No.3

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
MULTIPLE RESOURCE EVALUATION OF REGION 2, U.S. FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA

5. Report Date November 30, 1975

6. Performing Organization Code

7. Author(s)
Paula V. Krebs and Staff

8. Performing Organization Report No.

9. Performing Organization Name and Address
Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80302

10. Work Unit No.

11. Contract or Grant No. NAS5-20948

12. Sponsoring Agency Name and Address
Mr. Ed Szajna
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771 Code 902

13. Type of Report and Period Covered
Type II
September 1, 1975 to November 30, 1975

14. Sponsoring Agency Code

15. Supplementary Notes
Prepared in cooperation with the Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana; and U.S. Forest Service, Region 2, Denver, Colorado.

16. Abstract
Ground truth data from the summer's field work has been organized and reduced for computer evaluation of the vegetation classification. Test fields were selected using a mylar overlay of the field data and a band 7 grey scale of the intensive study quadrangles. LARS is preparing a vegetation classification using the modified clustering approach. The Forest Service is continuing work on the land use plan for the Southern San Juan Mountains Planning unit. Discussions between all participants in the consortium have raised many questions concerning the role of ecological inventory in Forest Service management decisions, and the need for a flexible system of the selective recall for vegetative and topographic information.

17. Key Words (Selected by Author(s))
U.S. Forest Service, ground truth training fields, modified clustering, resource data overlay, vegetation mapping, land use planning, landsystems inventory

18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unc.	Unc.	29	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

TYPE II THREE MONTH PROGRESS REPORT

For the period beginning September 1, 1975 and ending November 30, 1975

A. Title: Multiple Resource Evaluation of Region 2, United States Forest Service Lands Utilizing LANDSAT MSS Data

LANDSAT Contract No. NAS 5-20948

B. Principal Investigator: Dr. Paula Krebs
Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80302

GSFC Identification No. 376

C. Problems Encountered.

Late receipt of the aircraft coverage, Ames Flight No. 75-101, has delayed the initial phase of LARS analysis for a vegetation classification. Aerial photography is used to identify spectral classes from the individual cluster maps. This aerial coverage is also used to verify cover types and modify boundaries from the field data. Additional test fields are selected from this coverage. This information is utilized in an evaluation of the classification. Substantial progress toward these ends has been made since receiving the films in mid-October.

D. Accomplishments.

Much of the time during this reporting period was spent in the time consuming process of reducing the summer field data to an easily usuable format for analysis purposes. During discussions with the Forest Service many questions have been raised concerning the role of landtypes in their Ecological Land Units and in the planning process. The Laboratory for Applications of Remote Sensing (LARS) has begun development of the software for the overlaying of topographic data on LANDSAT data to use the terrain mapper.

D.1. Vegetation.

Many anxieties were relieved upon receipt of the NASA underflight coverage in early October. Each frame was placed in a protective plastic cover and the flight lines were plotted on USGS 2^{o} topographic maps.

The large quantity of ground truth collected during the summer field season was organized and reduced to make the data compatible with the computer systems at LARS. All information for each test data point was copied onto a 3X5" index card. These cards were arranged in numerical sequence and the data typed in tabloid form. Data from each test data point included: data point number, USGS topographic quadrangle where the point was located, date the data was collected, observers, cover type and total crown closure, crown closure breakdown by species, and additional notes concerning understory, disturbance, and general ecology of the area.

During field work each observer had a seperate topographic map with the data point grid marked on it. The field maps were merged onto one map and the cover types and boundaries clarified wherever necessary. This information was then transfered to a mylar base for each quadrangle where intensive field work was conducted. The mylar bases are easily duplicated and can be overlain on other base information such as topographic maps or computer generated grey scales and classifications. Before duplication of the mylars every test data point was checked for compatibility between the 3X5" cards, the typed sheets, the rough field maps, and the finished mylars. Errors were corrected and differences resolved before the field data was sent to LARS to be used in evaluating the digital classifications. Additional test fields were selected using photointerpretation of the aircraft coverage. A vegetation map of the Chama Valley was derived from photointerpretation. This map can be used for selection of training fields or test fields.

Automatic evaluation of a computer-derived classification is faster and easier using rectangular test fields than irregular test fields. Irregular test fields would require a manual overlay of the mylars on the completed classification and evaluating the printout pixel by pixel; or defining every pixel in the irregular test field for a computer evaluation. Rectangular test fields were selected by laying

a grey scale of an intensive quad over the mylar of field data for that quad. The systematic test point grid was used as a base. As large a rectangle as possible was drawn around each test data point with the following limitations: (Fig. 1)

1) the test data point was located somewhere within the test field, but not necessarily in the center,
2) there was a 1 pixel border between the test field and the boundry of the cover type,
3) the test field was homogenous with respect to cover type, crown closure and species composition.

Test data points on the boundry between two cover types, or test data points within one pixel of the boundry were not considered for test fields. This was to reduce the edge effect between cover types. Approximately 950 test fields were outlined on the grey scales for the intensive field study quads. The test fields encompassed about 15,200 pixels, or 1.9% of the Southern San Juan Mountains Planning Unit. Line and column coordinates were determined for every test field and recorded on computer data sheets with the cover types and species breakdown for LARS evaluation. Line and column coordinates for each individual test data point were also determined for LARS.

A "flat slope map" for slopes of 0^{o} - 5^{o} was generated by LARS from a classification of the slope data on the DODMA topographic tapes. This map was to be overlaid with the field data and some photointerpretation, and cover type mapped. This was an effort to find the spectral variation in various cover types without the variation inherent from different slopes and aspects often found in the complete set of LANDSAT data. However the DODMA topographic tapes were derived using 2^{o} topographic mapes and nterpolating between the 200' (6m) contour intervals. From an initial subjective evaluation, the flat slope maps did not line up with the flat areas shown on regular USGS 7½ maps. Further analysis is needed to find the validity of the topographic data for overlaying on the large scale maps. However, for generalized categories such as 0-15% slope the DODMA tapes are a useful tool.

Several meetings involving personnel from LARS, INSTAAR and Region 2, National Forest Service have defined the vegetation classes for initial and subsequest classifications by LARS (Table 1.). There have also been numerous discussions concerning landtypes, the sytem of Ecological Land Units, management decision, the planning process, and the application of a flexible results tape.

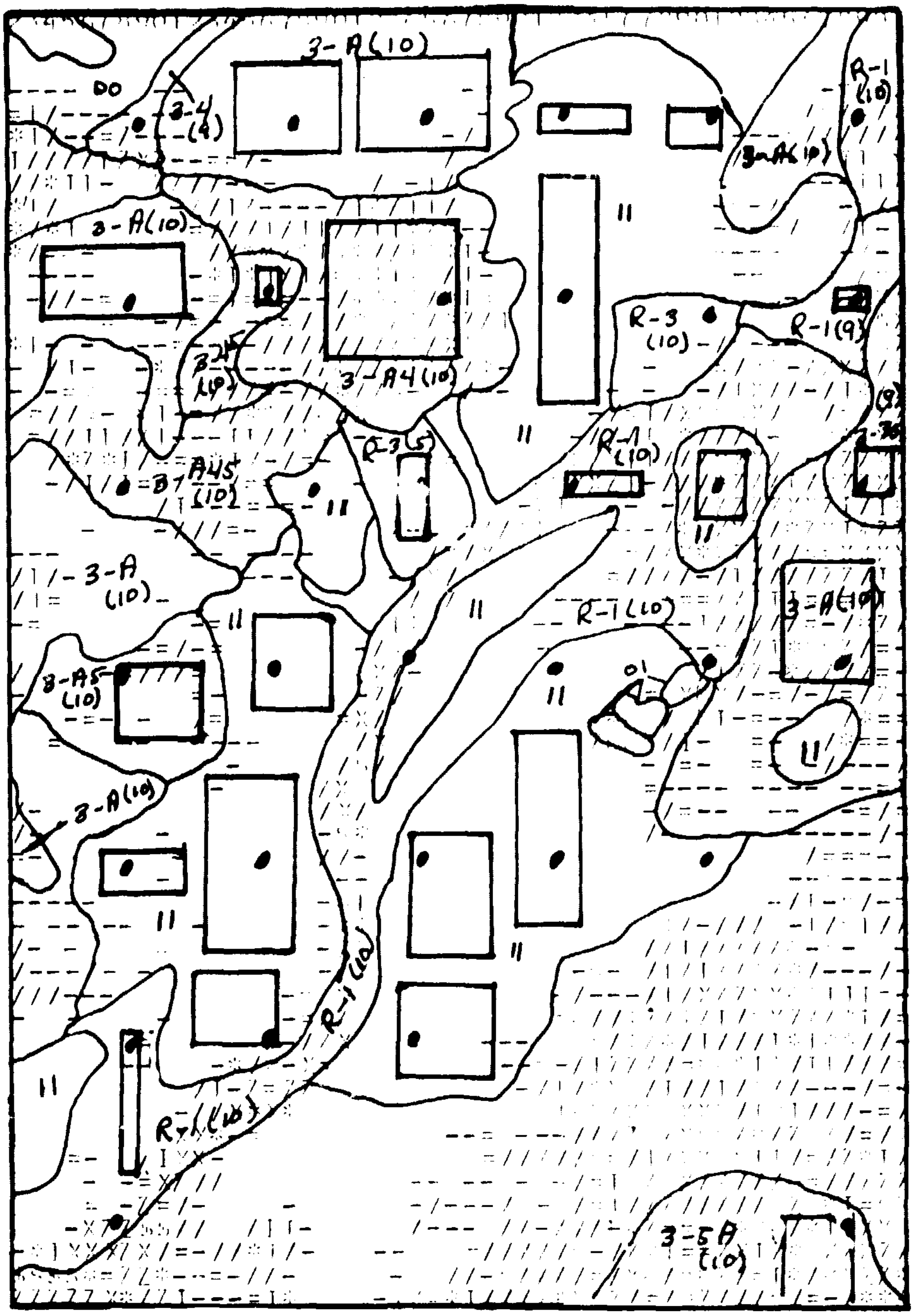


Figure 1. Example of test field selections. A portion of the grey scale of the Chromo NE quadrangle showing ground truth data from field work. Rectangular test fields are shown by heavy lines.

Table 1. Vegetation categories for computer-aided-analysis of LANDSAT MSS data. These are compatible with the Forest Service system at the habitat level.

Cover Types of Preliminary Classification	Modified Cover Types for Refined Classification
Water	
Barren Lands (bare rock/bare soil)	
Grassland	wet grassland
	dry grassland
Shrub	sage
	oak
Aspen	
Cottonwood-Willow (riparian)	
Pinon Pine-Juniper	
Ponderosa Pine	
Mixed Conifer	mixed conifer
	conifer-deciduous
Spruce-Fir	
Alpine	tundra
	alpine willow

D.2. Landtype Association.

A thorough study of the Forest Service's Land Systems Inventory (Wertz and Arnold, 1972) was conducted to determine the basis for the landtype classification and the reproducibility of the system. During this investigation many conflicts were found. These conflicts were mostly derived from unsystematic combination of topographic features, geologic origins and geomorphic processes, and a large degree of subjectivity on the part of the person doing the mapping. In order for any system of landtype analysis (regardless of the data base used) to be useful and operational from one area to another, the classification and descriptions of landtypes must be clearly defined and reproductible by many interpreters (see Section D.5.).

During the previous reporting period, LANDSAT data was analyzed for application to the landtype association and landtype levels of mapping. A previous interpreter (Krebs, 1975) concluded that LANDSAT data is a good tool for the landtype association levels, and consistency of interpretation is no problem. As an independent evaluation of both the method and the classification, an attempt was made to duplicate the results of this mapping effort using the same data and tools.

The same LANDSAT frames used in the previous analysis (1190-17145, band 5, 29 January, 1973 and 1191-17204, band 5, 30 January, 1973) were analyzed using the Zeiss 8X and 3X mirror stereoscope. Approximately the same amount of time was spent for the interpretation (about 6 hours) following the landtype association definitions of the Forest Service (Table 2).

The results (Figure 2) indicate wide disparity among the three interpretations. One reason is that the INSTAAR interpreters are less familiar with the area than the Forest Service personnel. Local relief is the key criterion for separating most of the categories, yet the relative relief that the interpreter "sees" may not be correctly calibrated to the actual numerical designations. Using a topographic map in conjunction with the LANDSAT frames may help calibrate the interpreter's sight. However, there is also the problem of what is meant by local relief. This could mean the amount of relief the landtype associations gives to the entire area, or it could relate to dissection relief within the landtype association boundaries. Local relief can be measured over any aerial extent from major drainage to high peaks, or from small tributaries to the top of the interfluve.

Both INSTAAR interpretations followed the method outlined in the previous report (Krebs et al, 1975). The lack of detail relative to the Forest Service map reflects both a lack of ground familiarity and a possible shortcoming of the LANDSAT data. It may also reflect the relative amount of time spent-one day for LANDSAT interpretation as opposed to five days of aerial photo interpretation by the Forest Service. The Forest Service map is not necessarily more accurate. This map was derived from the knowledge and subjective judgements of many different Forest Service personnel. The boundaries reflect a compromise among widely varying opinions within the Forest Service (Brock, 1975, personal communication), rather than a systematic evaluation of the data. It should also be noted that while the two INSTAAR maps are quite dissimilar, the

Table 2. Landtype Association.

Code	Name	Definition
01	Bottom Lands	More than 80% of an area gently sloping and local relief variation ranges from 0-100 feet. Characterized by alluvial deposits. Slope rarely exceed 15%.
05	Rolling uplands	50-80% of an area gently sloping, local relief variation ranges from 300-1000 feet and more than 50% of gentle slope is on upland.
13	Smooth Low Hills	20-50% of an area gently sloping and local relief variation ranges from 100-300 feet.
14	Smooth Mountain Lands	20-50% of an area gently sloping and local relief variation ranges from 300-500 feet.
19	High Hills	Less than 20% of an area gently sloping and local relief variation ranges from 500-1000 feet.
20	Igneous Fluvial (Uneven Mountain Land)	Less than 20% of an area gently sloping and local relief variation ranges from 1000-3000 feet.
22	Canyon - Scarp Lands	Extremely steep (75% plus) cliffs and rims, dominated by rock outcrops and colluvial slopes.
23	Glacial Depositional	Undulating to hilly landforms resulting from glacial deposition. Moraines, tills and outwashes typify the landscape.
24	Rock Outcrops	Exposures of bare rock greater than 80%.
25	Landslide Depositional	Areas of downward sliding or falling of relatively dry mass of earth, rock, or mixture of the two which have become loosened from a hillside by moisture, snow or man.

8 a

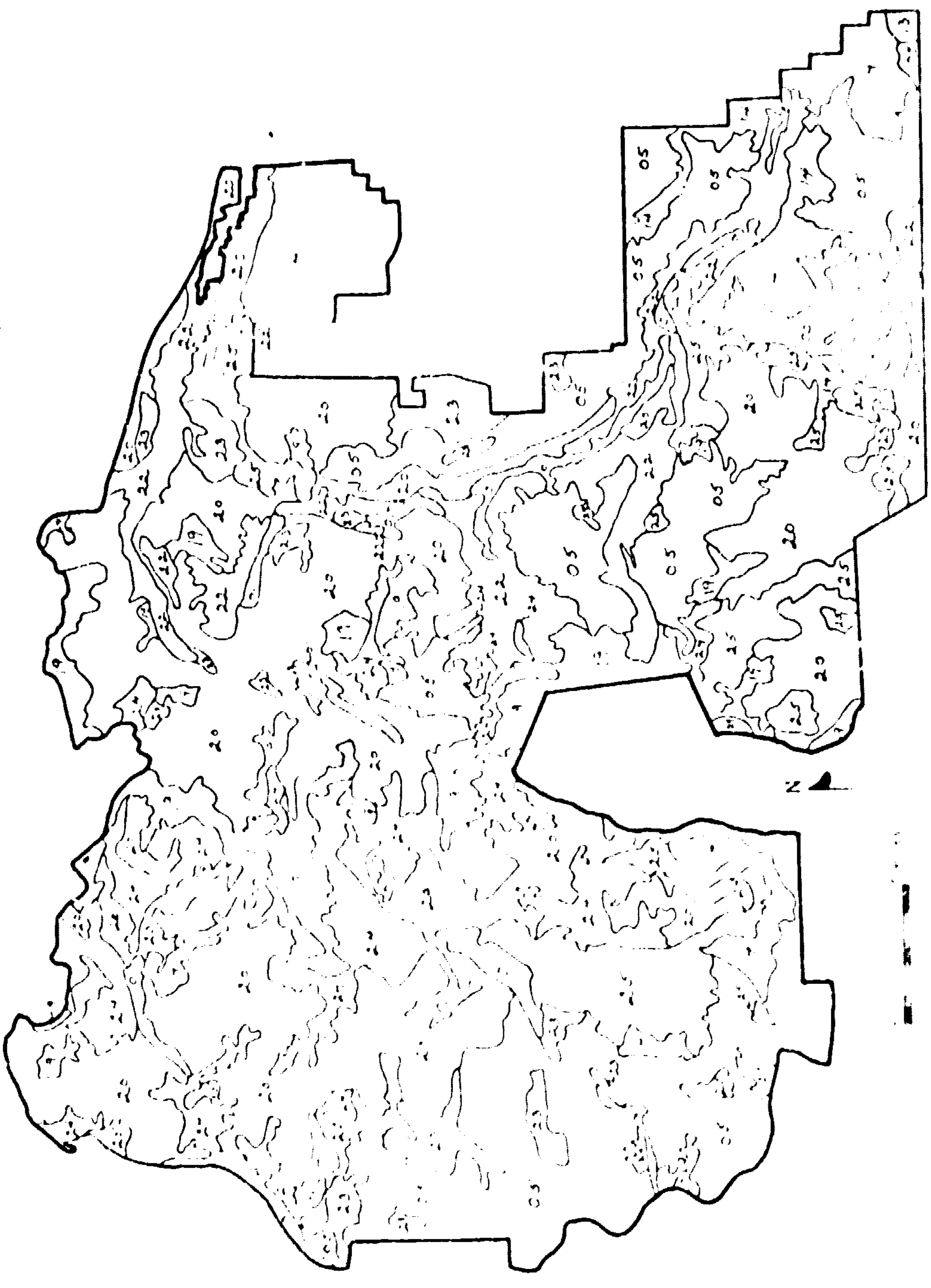
Figure 2. A comparison of the landtype association maps derived by the U.S. Forest Service, Region 2, and two seperate INSTAAR interpreters.

a. U.S. Forest Service, Region 2
b. INSTAAR interpreter 1
c. INSTAAR interpreter 2

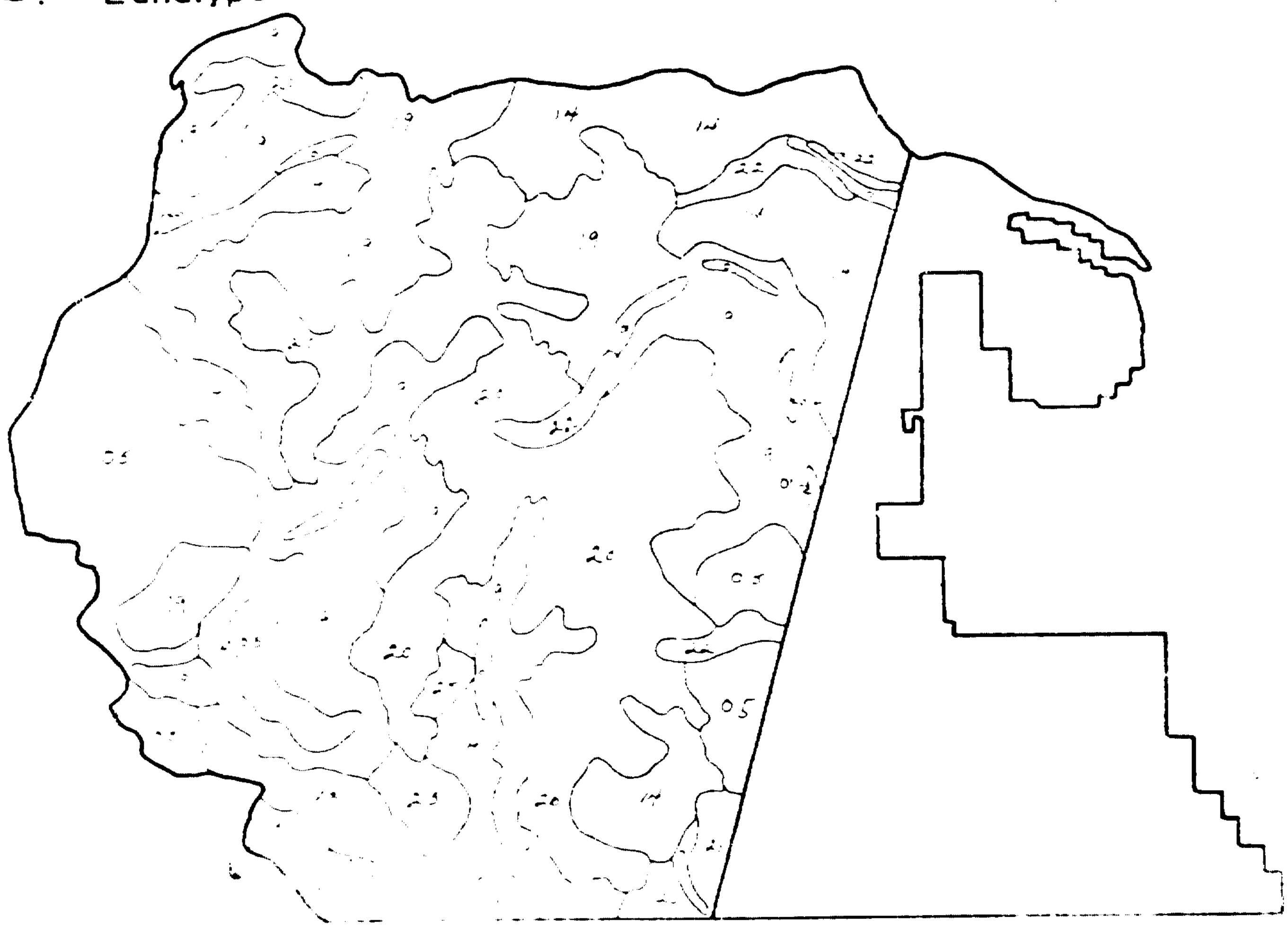
Key for landtype association maps:
(refer to Table 2 for landtype descriptions)

Code	Name
01	Bottom lands
05	Rolling uplands
13	Smooth low hills
14	Smooth mountain lands
19	High hills
20	Igneous fluvial
22	Canyon-scarp lands
23	Glacial depositional
24	Rock outcrops
25	Landslide depositional

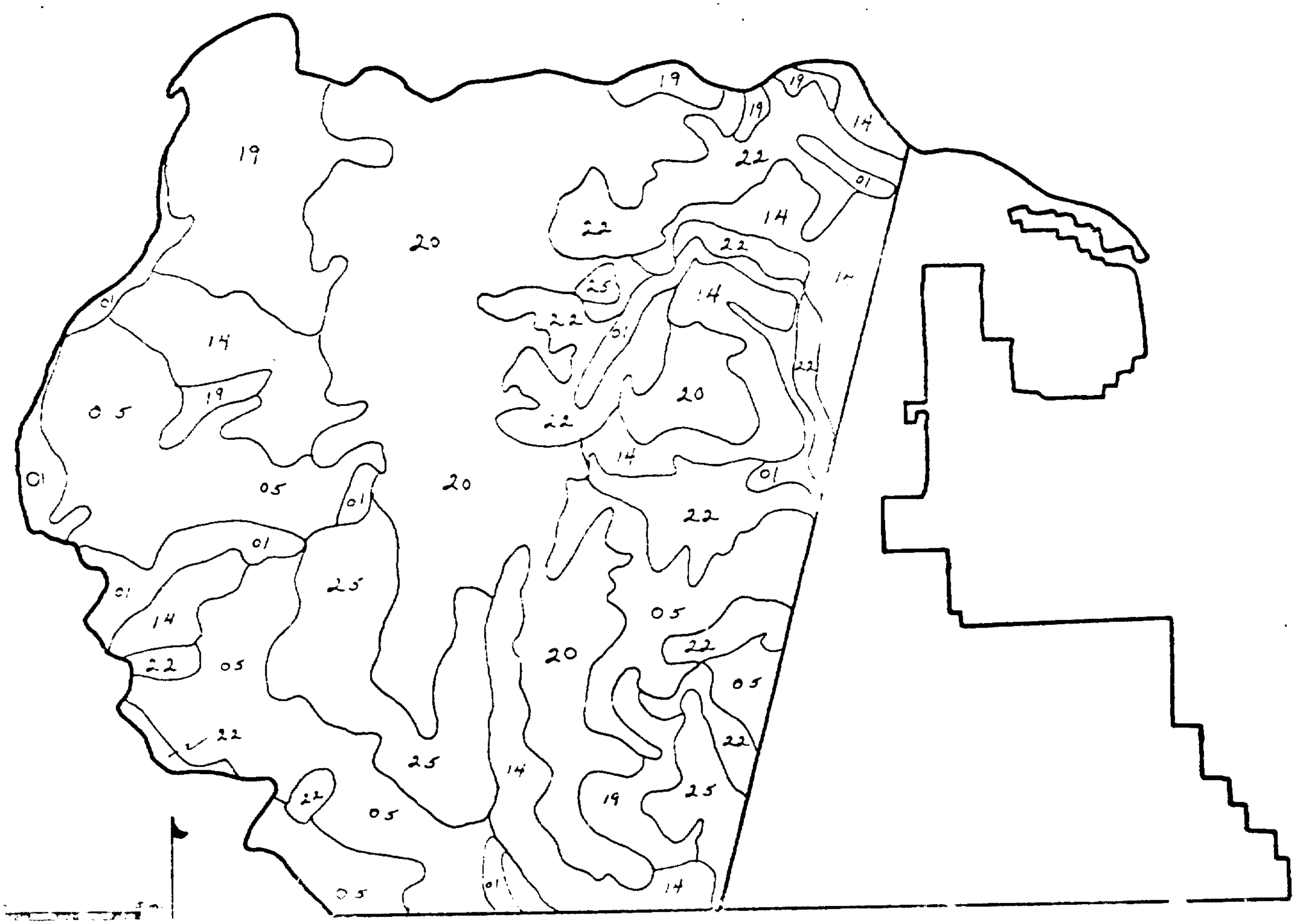
A. Landtype associations - Forest Service Interpretation



B. Landtype associations - INSTAAR Interpreter 2



C. Landtype associations - INSTAAR Interpreter I.



same method was used. This suggests that the classification and definitions developed by the Forest Service need some reworking. The problems are further discussed in Section D.5.

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Krebs, P.V. 1975. Multiple Resource Evaluation of Region 2 U.S. Forest Service Lands Utilizing LANDSAT MSS DATA. Second quarterly report for the period June 1, 1975-August 31, 1975. Prepared for National Aeronautics and Space Administration, Goddard Space Flight Center, 25 pp.

Wertz, W.A. and J.F. Arnold. 1972. Land Systems Inventory. Dept. of Agriculture, U.S Forest Service Intermountain Region, Division of Soil and Water Management, Ogden, Utah, 12 pp.

D.3. Computer-aided techniques by LARS.

Activities of LARS involved the following:

1) Classification of topographic data from DODMA tapes,

2) Maximum likelihood classification of a data set combining topographic data and LANDSAT MSS data,

3) Unsupervised classification which derived 12 spectral classes,

4) Production of sample products for consortium representatives.

A procedure was developed to utilize the topographic data so that grouped areas of similar elevation, slope or aspect characteristics could be displayed in line printer or digital display output format. The source of this data is the DODMA topographic tapes. The information contained on the reformatted data tapes is so detailed that it is difficult to interpret in either output format. For example, aspect is coded in 1° increments, but this is more detailed than the researcher needs. Generalized displays of the aspect, slope, and elevation characteristics of the test site area are more useful. The procedure that has been developed involves the classification of the topographic data into elevation, slope, or aspect increments that can be specified by the U.S. Forest Service. This procedure for grouping the elevation, slope, and aspect data was developed and tested during this reporting period. Examples of the output formats were shown to INSTAAR and U.S Forest Service personnel during the review meeting on October 31, 1975 in Durango, Colorado.

A second aspect of LARS activities involved definition of the analysis procedure to be used in combining topographic data with the multispectral scanner data available from LANDSAT. Since the computer works with data vectors, these vectors can be composed of a combination of spectral data from various wavelength bands, as well as elevation, slope and aspect parameters. The standard maximum likelihood classification technique can be used with such a combination data set. However, in preliminary tests using this standard technique, the classification results did not truly reflect the impact of elevation on the classification performance. When elevation is simply included as another data value in the data vector with the spectral data obtained by LANDSAT, the results did not appear to have as good a classification of cover types as felt possible. Therefore, it is believed that the layered classifier technique instead of the maximum likelihood classification technique, should be used for more effective analysis of the combination of topographic and spectral data. Modifications of the layered classifier software are being made to effectively use this technique for analyzing the combination topographic/spectral data.

The third area of analysis involved a computer classification of the Southern San Juan Mountain Planning Unit using an unsupervised or clustering approach. The Wilkes-Lambda value was used to define the "opti-

mum" number of spectral classes present in the test site. Every fifth line and column of data were used to develop the training statistics for the classification. Twelve spectral classes were defined and used to classify the data. Subjective evaluation of the classification results indicate the classification is not satisfactory. Several informational classes were not accurately mapped using the statistics developed with this clustering analysis procedure. The interpretiation is that a straight clustering approach may work well for amll geographic areas, but is unsatisfactory when applied to large geographic areas. Hopefully, a modified clustering approach will provide better cover type classification. Such modified cluster analysis will be completed during the next quarter.

Several sets of line printer display materials were prepared to familiarize Forest Service personnel with the format and type of output product that can be obtained with computer-aided analysis techniques. At the meeting in Durango a discussion developed concerning the scale and format output that would be most useful to Forest Service personnel. Particular interest was expressed in the classification output using the ECHO classifier (boundry locater). After a satisfactory classification using the modified clustering technique has been achieved for the Southern San Juan Mountain Planning Unit, a classification using the ECHO classifier should be pursued.

To aid in further communications with Forest Service Personnel, INSTAAR was provided with a series of line printer displays. The displays included classifications of slope, aspect, elevation and vegetation for the Vallecito Reservoir area in the Granite Peak test site(SKYLAB contract NAS9-13380). A copy of the un-supervised classification for the entire Southern San Juan Mountains Planning Unit was provided for subjective evaluation by INSTAAR.

D. 4. U.S. Forest Service Planning Effort.

An Ecological Land Unit (ELU) is the basic entity for the Southern San Juan Mountains Planning Unit. An ELU is a unique combination of vegetation and categories of land systems. The vegetation system is at the habitat level of inventory and the land system is at the subsection level of landtype association (Table 3). Sixty-one types of ELU's have been derived for the Southern San Juan Mountains Planning Unit.

These ELU's are then evaluated for management implications by assessing capability, suitability, availability, and compatibility for specific resource uses. Capability is best defined as the potential of a parcel of land to provide a given resource. Suitability is a measure of productivity for that resource and whether or not the resource is renewable. If a parcel of land has been indicated to be capable and suitable for a specific resource, the availability must be determined, i.e. has that parcel of land already been allocated for another use. Every parcel of land is considered for each of the following resources to be managed: forested land-commercial and non-commercial, recreation, habitat, water, and visual resource. Some overlap is expected among these resources and a parcel of land may have several possible resource uses. These resource uses must be compared for compatibility.

The management implications and current management situation are reviewed before defining the management direction with possible alternatives. From this, land allocations and management decisions are made. At this point the land use plan can be formulated. The stepwise and integrated process is summarized in figure 3.

Obviously many of the judgements called for in developing the land use plan require additional detailed data. A set of essential characteristics to make such judgements is being compiled. This is an attempt to reduce the subjectivity in the planning process. Many of these characteristics are topographic or may be inferred from topography.

The use of LANDSAT MSS data to derive a map product of landtype associations and a vegetation classification may provide an avenue for formulation of Ecological Land Units. Currently a manual overlay approach is used to combine and recombine detailed resource data for the needs of the planning process. The digitized topographic data (DODMA topography tapes) have been overlaid on LANDSAT MSS digital data. Upon completion of the vegetation classification by computer-aided analysis an anticipated product will be a results tape. The inclusion of vegetation, elevation, slope aspect, and slope percent on this tape will eliminate the time consuming manual overlay.

The development of a software package for selective recall of combined features from this tape is being discussed with the ADP division of Region 2 offices. This hopefully will provide a tool for long range land use planning and day-to-day use by forest personnel.

TABLE 3. LEVELS OF LAND SYSTEMS INVENTORY (after Wertz and Arnold, 1972)

LEVEL	EXAMPLE	MAPPING SCALE	UNIT SIZE	APPLICATION
Physiographic Province	Southern Rocky Mountains	1:1,000,000	1000's of sq. mi.	Nationwide or broad regional data summary
Section	San Juan Mountains	1:500,000	100's to 1000's of sq. mi.	Broad regional summary. Basic geologic, climatic, vegetative data for design of individual resource inventories.
Subsection	Glaciated Mountains	1:250,000	10's to 100's of sq. mi.	Strategic management direction, broad area planning.
Landtype Association	Uneven Mountian Land	1:60,000 1:20,000	1 to 10's of sq. mi.	Summary of resource information and resource allocation.
Landtype	Ridge	1:20,000	1/10 to 1 sq. mi.	Comprehensive planning, resource plans, development standards, local zoning.
Landtype Phase	-----------	1:20,000 or larger	1/100 to 1/10 sq. mi.	Project development plans
Site	-----------	not generally mapped	acres or less	Detailed on-site action programs.

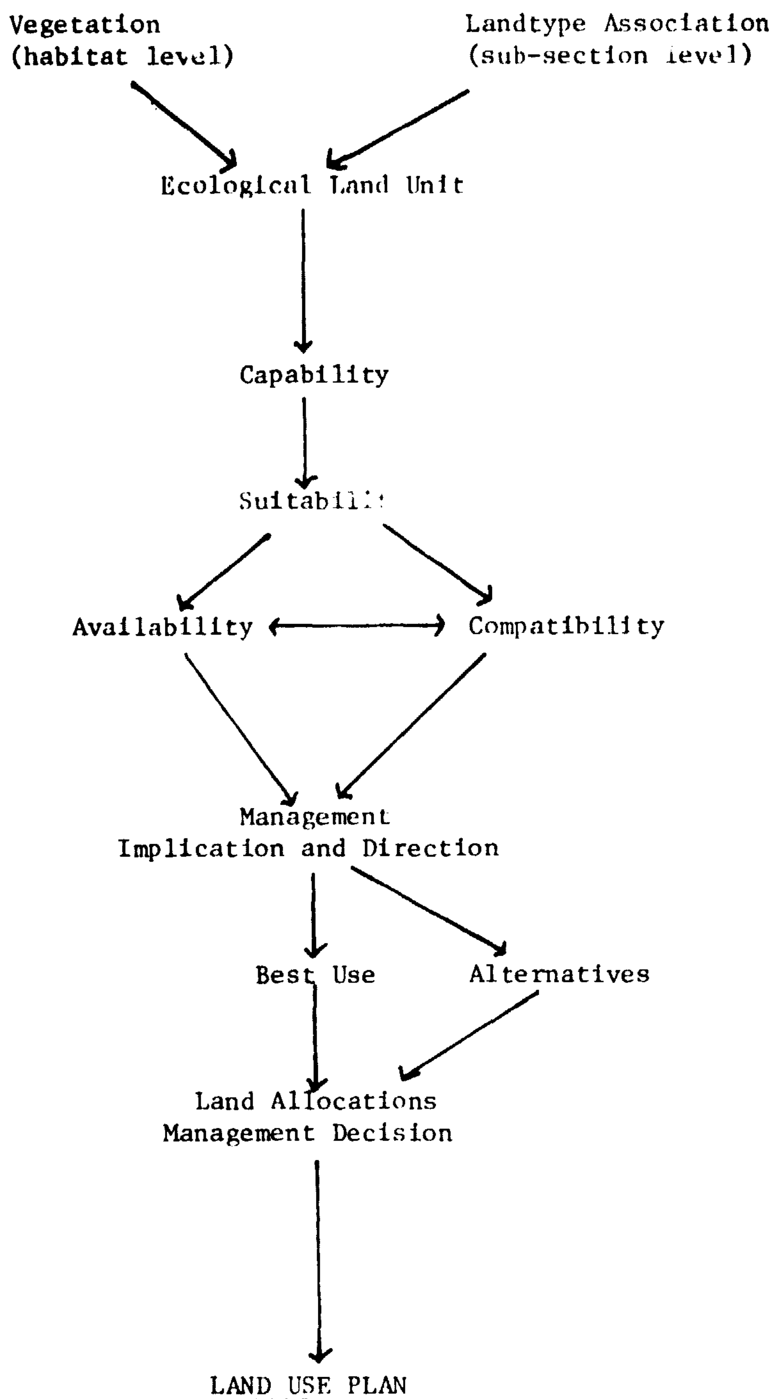

Figure 3. Flow diagram of the stepwise process in developing a land use plan.

D.5. INSTAAR Evaluation of Land Systems Inventory.

As part of further testing of the applicability of LANDSAT data to Forest Service land use planning, it was necessary to first understand the land system classification in use. The Forest Service uses the Land Systems Inventory as outlined by Wertz and Arnold (1972) at all levels of land use planning. The land system is based on a hierarchical breakdown of landtypes from a broad level to more detailed, homogeneous units. Several problems with the Southern San Juan Mountains system became evident, both from a theoretical standpoint (ie., the guidelines of Wertz and Arnold, 1972) and from a practical standpoint (ie., utility and reproducibility). Under the Land Systems Inventory hierarchy the San Juan Mountains are a section of the Southern Rocky Mountain Province, which is further divided into subsections glaciated mountain land and fluvial mountain land (Table 2).

Ideally, each subsection would have unique landtype associations which would be composed of unique landtypes. The landtype association (Table 2) are mostly topographic entities which can occur in both glaciated and fluvial mountain lands. The landtypes (Table 4) are not subdivisions of the landtype association, but rather are different subdivisions of the entire planning unit. For example, sideslopes will be found in smooth low hills, smooth mountain lands, high hills, and several others. Thus, a sideslope is not a more homogeneous and discrete unit of a landtype association but a completely different unit based on a different set of perameters. The landtypes crosscut the landtype associations which in turn crosscut the subsections instead of being subdivisions of the higher units.

The basis of both the landtype associations and landtypes is not consistent within either classification. The inconsistency creates problems in indentification of the units and in interpretation for land use planning decisions, For example, the basis for most of the landtype associations is topographic in nature, ie., slope and local relief (Table 2). Glacial depositional and landslide depositional are genetic classes and will overlap many if not all of the categories. Glacial depositional features, described as "hilly to undulating" and typified by "moraines, tills, and outwashes", could easily be mapped as rolling uplands or bottomland, or mountain land depending on the age of glaciation. Landslides will be concentrated along outcrops of unstable geologic formations, such as the Mancos Shale, but can also be found witnin any topographic regime. Rock outcrops are included as part of the description of canyon-scarplands but are also mapped separately. Base geologic maps can be used if available. But there seems to be inconsistencies as to the selection of genetic features to be incorporated in the classification.

Similar inconsistencies occur in the present landtype level. The entire planning unit can be mapped as ridge, sideslope or toeslope. However, some small features are arbitrarily subdivided out of these units, and are given relatively more importance by being mapped separately. Alluvial fans are small scale toeslope features; floodplains and benches are small scale bottomland features. The detail in mapping these features is inconsistent with the lack of detail in units such as sideslope. Alpine is a vegetation descriptor, not a landform. Alluvium and till are not

Table 4. Landtype Definitions.

Ridge	A destructional denudational form which is a narrow elongated crest of a hill or mountain.
Flat	A remnant of a structural surface which is a broad and nearly level upland area.
Sideslope	A constructional denudational form which occupies the undifferentiated inclined portions of mountain land, found below the local interfluve and above the fluvial bottomlands. A sideslope is composed of colluvium or colluvial-mantelled bedrock.
Toeslope	A constructional denudational form which is the depositional zone at the base of a hillslope and transitional to lowlands. It is distinguished from sideslope by a discrete change in slope gradiant.
Bench	A destructional fluvial-denudational form which is long and narrow, gently inclined and built from constructional fluvial processes.
Floodplain	A constructional fluvial form which is adjacent to a river channel and inundated during annual highwater periods.
Alluvium	A constructional fluvial form which is composed of sand, gravel, cobbles or other transported material. Alluvium includes glacial outwash, or stratified drift that is stream built from glacial meltwater.
Alluvial Fan	A cone-shaped constructional fluvial-denudational form resulting from a tributary of high declivity running into the valley of a stream with less declivity. Alluvial fans include debris fans, or cone-shaped constructional denudational forms.
Landslide	Any constructional denudational form which displays evidence or a history of perceptible unit downward movement of a portion of the land surface.
Till	Any constructional glacial form.
Bare Rock	A miscellaneous landtype which occurs under all geologic formation processes and consists of any surface with more than 90% bare rock.
Alpine	A miscellaneous landtype which is the land surface above the absolute tree limit.

landforms, but deposits which occur in floodplains, benches, and alluvial fans, or moraines. It is inconsistencies such as these which make the system difficult to understand and interpret.

Ideally, any system should be based on the key parameters for the specific land use decisions. In the Southern San Juan Mountains, each landtype association supposedly reflects six essential characteristics which the Forest Service will consider when allocating activities, uses, and resources. The essential characteristics are average precipitation, elevation range, slope (average and range), relative productivity, mass movement potential, and erosion hazard. When landtypes are combined with two vegetation parameters, cover type and productivity, these form the Ecological Land Units which serve as the base data for planning (see Section D.4). Unfortunately, these characteristics do not really define the landtype associations but merely describe them in a general way after they have been mapped. For example, half of the landtype associations are described by a slope range of 10% to 60%, and six of the ten have an average slope of about 45%. Mass movement potential is variable within each landtype association category depending on slope, and doesn't really define those categories. The characteristics of both landslide depositional and glacial depositional are nearly identical except for origin. The landtypes themselves, which are such an integral part of the ELU's, do not accurately reflect the essential characteristics. After ELU's are defined and mapped, each area must still be examined in detail before management decisions can be made.

Subjectivity is the main reason that the landtype classification in the Southern San Juan Mountains is not systematic. The final classifications are a collection of the subjective judgements of many different Forest Service personnel. Each individual has that "gut feeling" about the nature of each area being mapped and how each area may react to different land uses. The Forest Service knows that certain areas are naturally unsuited for timber harvest. But why? What are the parameters that make an area suitable or unsuitable for a particular land use? Because the limiting parameters for each use or resource have not yet been identified, and because the landtype associations do not reflect a systematic grouping of these parameters, the land use decisions will be based on subjectivity. However, in view of the limited time factor, the landtype associations (and the ecological land units) are the best sources of information the decision makers have. The point here is that defensible management decisions should be based on a systematic evaluation of the limiting parameters for each land use and good base data derived for these parameters. The land systems currently used may be functional to a degree, but needs to be revised as soon as better base data is available.

D.6. Projected Activities.

When the initial vegetation classification by the modified clustering technique used by LARS is completed and evaluated, the INSTAAR personnel will meet with the Region 2 & 3 Forest Service planning team. These meetings will begin the interpretative phase of this project. As LARS develops the terrain mapping and refines the vegetation classification, the INSTAAR and Forest Service personnel will interpret the digital mode of processing and evaluate its usefulness in the system of ELU's and the Forest Service planning efforts. Complete documentation for all mapping categories will be developed as the Forest Service finishes their work with defining ELU's.

Landform mapping from a variety of LANDSAT data products will continue during the next quarter but with slightly different emphasis. The LANDSAT data will be tested to the level of landtypes without restricting the activity to the classification developed earlier. Manipulation of standard products will be emphasized since these are more readily available to the Forest Service and less expensive than most other computer products.

Among planned activities are:

1) evaluation of summer and early winter imagery for drainage pattern analysis and its relation to geologic features,

2) evaluation of stereo pair reversals for mapping bottom land and toe-slope features,

3) establishing a standard set of negative and positive diazo transparencies and evaluating different color and band combination for landform mapping,

4) evaluation of various combinations of different seasons, bands, and positives/negatives for landform mapping,

5) evaluation of various digital display products.

E. Significant Results.

No significant results are identified during this reporting period.

F. Publications.

No publications or presentations were completed during this reporting period.

G. Recommendations.

In view of the cost of providing aircraft coverage, every attempt should be made to provide high quality data. The addition of an anti-vignetting filter on the camera systems should be a requisite. If the conditions even remotely indicate an improvised product can be obtained through the use of such a filter, there should be no hesitancy in prescribing its inclusion for the camera system.

Although Ames Flight No. 75-101 was to provide 10% endlap and 10% sidelap as originally designated, 50% or greater endlap was obtained. We are not complaining, but rather praising. Again, to provide high quality data which is useful for most interests, stereo coverage is mandatory. The major cost is in aircraft operation and crew salaries. In comparison the cost of film is nominal. The additional frames necessary to provide stereo coverage should not be a limiting factor if the flight is authorized.

H. Aircraft Data.

The aircraft coverage provided by Flight No. 75-101, Ames Research Center is of immeasurable benefit to this study. The larger scale HR-732 photography covers 40% of the study area. Selection of training areas for computer-aided analysis is being made from this film. Spectral classes from each cluster map are identified as to vegetation cover type from the air photos. This is the initial interpretive phase in the development of a classification utilizing LANDSAT MSS data. The quality of information input at this point directly influences the classification results.

The small scale RC-10 coverage is augmenting the detailed data collected during the field season. A verification of the vegetation covertype is made from this coverage and boundary modifications are now possible. This combined data set is being used to delineate test fields for an evaluation of the classification derived by computer-aided analysis of LANDSAT MSS data. LANDSAT image interpretation at the landtype association level can be verified using the RC-10 coverage. Those mapping categories not detectable on the LANDSAT imagery can be added using this aircraft coverage. The map framework is provided by LANDSAT image interpretation and special categories are then added from air photo interpretation.

I. Data Use.

Value of data allowed	$1,536
Value of data ordered	$1,292
Value of data received	$1,292

Difficulty was encountered in obtaining information on Ames Research Center Flight No 75-101, flown on 25 June, 1975. Following repeated contact with EROS Data Center and Dr. Price, GSFC, the flight summary report was received. An order was immediately placed for the HR-732 and RC-10 coverages. Edmond Szajna, technical monitor, was notified of the purchase request and account monies were shifted from the CCT account to the aircraft account to cover the cost of $834.00.

As no aircraft data previously was available for the majority of the study area, the acquisition of any coverage was gratefully received. The quality of the frames are quite good. An improvement would have been the use of an anti-vignetting filter on both sensors. The HR-732 coverage is proving to be extremely useful for the detail necessary to select training fields for computer-aided analysis in techniques.

Since the RC-10 coverage has a 55-60% endlap over the mountainous area, photointerpretation for vegetation covertypes is greatly improved. This aircraft data is being used to supplement the detailed field work in providing test fields for evaluation of classification results obtained by computer-aided analysis.

J. Funds Expended.

First Quarter		$14,334
Second Quarter		$10,831
Third Quarter		
Salaries & wages	$8,286	
*Indirect costs, supportive services	$7,434	
Travel & field expenses	$1,718	
Materials	$ 630	
Subtotal	$18,068	$18,068
Subcontract		$61,876
	Total	$105,109

* Includes $4,555 supportive services at Mountain Research Station for the remainder of the contract period to May 20, 1976. These monies are utilized as services provided by an overhead assessment.

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CR-146039

MULTIPLE RESOURCE EVALUATION OF REGION 2 U.S. FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA

(E76-10106) MULTIPLE RESOURCE EVALUATION OF REGION 2, US FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA Quarterly Progress Report, 1 Sep. - 30 Nov. 1975 (Colorado Univ.) 31 p HC $4.00 CSCL 08B
N76-16529
Unclas
G3/43 00106

PAULA V. KREBS and STAFF
Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80302

in cooperation with

Roger M. Hoffer and Staff
Laboratory for Applications of Remote Sensing
Purdue University
1220 Potter Drive
West Lafayette, Indiana 47907

and

Region 2 U.S. Forest Service, U.S.D.A.
P. O. Box 25127
Denver, Colorado 80225

November 1975, QUARTERLY PROGRESS REPORT
For Period September 1 - November 30, 1975

NASA CONTRACT NAS 5-20948

Prepared for
GODDARD SPACE FLIGHT CENTER 23760
Greenbelt, Maryland 20771

1. Report No. Type II, No.3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle MULTIPLE RESOURCE EVALUATION OF REGION 2, U.S. FOREST SERVICE LANDS UTILIZING LANDSAT MSS DATA		5. Report Date November 30, 1975
		6. Performing Organization Code
7. Author(s) Paula V. Krebs and Staff		8. Performing Organization Report No.
9. Performing Organization Name and Address Institute of Arctic and Alpine Research University of Colorado Boulder, Colorado 80302		10. Work Unit No.
		11. Contract or Grant No. NAS5-20948
		13. Type of Report and Period Covered Type II September 1, 1975 to November 30, 1975
12. Sponsoring Agency Name and Address Mr. Ed Szajna National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland 20771 Code 902		14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Laboratory for Applications of Remote Sensing, Purdue University, W. Lafayette, Indiana; and U.S. Forest Service, Region 2, Denver, Colorado.

16. Abstract

Ground truth data from the summer's field work has been organized and reduced for computer evaluation of the vegetation classification. Test fields were selected using a mylar overlay of the field data and a band 7 grey scale of the intensive study quadrangles. LARS is preparing a vegetation classification using the modified clustering approach. The Forest Service is continuing work on the land use plan for the Southern San Juan Mountains Planning unit. Discussions between all participants in the consortium have raised many questions concerning the role of ecological inventory in Forest Service management decisions, and the need for a flexible system of the selective recall for vegetative and topographic information.

17. Key Words (Selected by Author(s)) U.S. Forest Service, ground truth training fields, modified clustering, resource data overlay, vegetation mapping, land use planning, landsystems inventory	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unc.	Unc.	29	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

TYPE II THREE MONTH PROGRESS REPORT

For the period beginning September 1, 1975 and ending November 30, 1975

A. Title: Multiple Resource Evaluation of Region 2, United States Forest Service Lands Utilizing LANDSAT MSS Data

LANDSAT Contract No. NAS 5-20948

B. Principal Investigator: Dr. Paula Krebs
Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80302

GSFC Identification No. 376

C. Problems Encountered.

Late receipt of the aircraft coverage, Ames Flight No. 75-101, has delayed the initial phase of LARS analysis for a vegetation classification. Aerial photography is used to identify spectral classes from the individual cluster maps. This aerial coverage is also used to verify cover types and modify boundaries from the field data. Additional test fields are selected from this coverage. This information is utilized in an evaluation of the classification. Substantial progress toward these ends has been made since receiving the films in mid-October.

D. Accomplishments.

Much of the time during this reporting period was spent in the time consuming process of reducing the summer field data to an easily usuable format for analysis purposes. During discussions with the Forest Service many questions have been raised concerning the role of landtypes in their Ecological Land Units and in the planning process. The Laboratory for Applications of Remote Sensing (LARS) has begun development of the software for the overlaying of topographic data on LANDSAT data to use the terrain mapper.

D.1. Vegetation.

Many anxieties were relieved upon receipt of the NASA underflight coverage in early October. Each frame was placed in a protective plastic cover and the flight lines were plotted on USGS 2^{o} topographic maps.

The large quantity of ground truth collected during the summer field season was organized and reduced to make the data compatible with the computer systems at LARS. All information for each test data point was copied onto a 3X5" index card. These cards were arranged in numerical sequence and the data typed in tabloid form. Data from each test data point included: data point number, USGS topographic quadrangle where the point was located, date the data was collected, observers, cover type and total crown closure, crown closure breakdown by species, and additional notes concerning understory, disturbance, and general ecology of the area.

During field work each observer had a seperate topographic map with the data point grid marked on it. The field maps were merged onto one map and the cover types and boundaries clarified wherever necessary. This information was then transfered to a mylar base for each quadrangle where intensive field work was conducted. The mylar bases are easily duplicated and can be overlain on other base information such as topographic maps or computer generated grey scales and classifications. Before duplication of the mylars every test data point was checked for compatibility between the 3X5" cards, the typed sheets, the rough field maps, and the finished mylars. Errors were corrected and differences resolved before the field data was sent to LARS to be used in evaluating the digital classifications. Additional test fields were selected using photointerpretation of the aircraft coverage. A vegetation map of the Chama Valley was derived from photointerpretation. This map can be used for selection of training fields or test fields.

Automatic evaluation of a computer-derived classification is faster and easier using rectangular test fields than irregular test fields. Irregular test fields would require a manual overlay of the mylars on the completed classification and evaluating the printout pixel by pixel; or defining every pixel in the irregular test field for a computer evaluation. Rectangular test fields were selected by laying

a grey scale of an intensive quad over the mylar of field data for that quad. The systematic test point grid was used as a base. As large a rectangle as possible was drawn around each test data point with the following limitations: (Fig. 1)

1) the test data point was located somewhere within the test field, but not necessarily in the center,
2) there was a 1 pixel border between the test field and the boundry of the cover type,
3) the test field was homogenous with respect to cover type, crown closure and species composition.

Test data points on the boundry between two cover types, or test data points within one pixel of the boundry were not considered for test fields. This was to reduce the edge effect between cover types. Approximately 950 test fields were outlined on the grey scales for the intensive field study quads. The test fields encompassed about 15,200 pixels, or 1.9% of the Southern San Juan Mountains Planning Unit. Line and column coordinates were determined for every test field and recorded on computer data sheets with the cover types and species breakdown for LARS evaluation. Line and column coordinates for each individual test data point were also determined for LARS.

A "flat slope map" for slopes of 0° - 5° was generated by LARS from a classification of the slope data on the DODMA topographic tapes. This map was to be overlaid with the field data and some photointerpretation, and cover type mapped. This was an effort to find the spectral variation in various cover types without the variation inherent from different slopes and aspects often found in the complete set of LANDSAT data. However the DODMA topographic tapes were derived using 2° topographic mapes and nterpolating between the 200' (6m) contour intervals. From an initial subjective evaluation, the flat slope maps did not line up with the flat areas shown on regular USGS 7½ maps. Further analysis is needed to find the validity of the topographic data for overlaying on the large scale maps. However, for generalized categories such as 0-15% slope the DODMA tapes are a useful tool.

Several meetings involving personnel from LARS, INSTAAR and Region 2, National Forest Service have defined the vegetation classes for initial and subsequest classifications by LARS (Table 1.). There have also been numerous discussions concerning landtypes, the sytem of Ecological Land Units, management decision, the planning process, and the application of a flexible results tape.

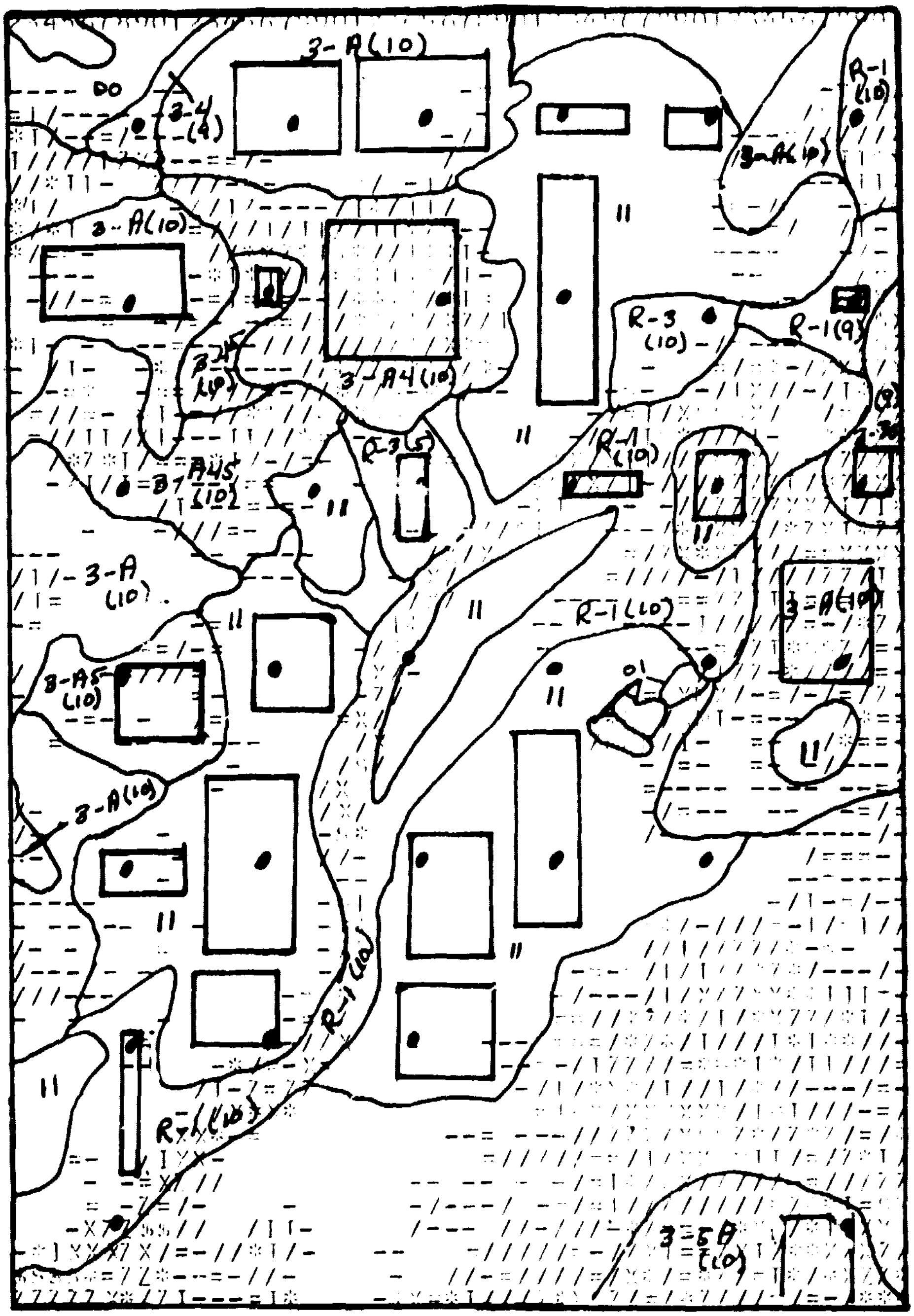


Figure 1. Example of test field selections. A portion of the grey scale of the Chromo NE quadrangle showing ground truth data from field work. Rectangular test fields are shown by heavy lines.

Table 1. Vegetation categories for computer-aided-analysis of LANDSAT MSS data. These are compatible with the Forest Service system at the habitat level.

Cover Types of Preliminary Classification	Modified Cover Types for Refined Classification
Water	
Barren Lands (bare rock/bare soil)	
Grassland	wet grassland
	dry grassland
Shrub	sage
	oak
Aspen	
Cottonwood-Willow (riparian)	
Pinon Pine-Juniper	
Ponderosa Pine	
Mixed Conifer	mixed conifer
	conifer-deciduous
Spruce-Fir	
Alpine	tundra
	alpine willow

D.2. Landtype Association.

A thorough study of the Forest Service's Land Systems Inventory (Wertz and Arnold, 1972) was conducted to determine the basis for the landtype classification and the reproducibility of the system. During this investigation many conflicts were found. These conflicts were mostly derived from unsystematic combination of topographic features, geologic origins and geomorphic processes, and a large degree of subjectivity on the part of the person doing the mapping. In order for any system of landtype analysis (regardless of the data base used) to be useful and operational from one area to another, the classification and descriptions of landtypes must be clearly defined and reproductible by many interpreters (see Section D.5.).

During the previous reporting period, LANDSAT data was analyzed for application to the landtype association and landtype levels of mapping. A previous interpreter (Krebs, 1975) concluded that LANDSAT data is a good tool for the landtype association levels, and consistency of interpretation is no problem. As an independent evaluation of both the method and the classification, an attempt was made to duplicate the results of this mapping effort using the same data and tools.

The same LANDSAT frames used in the previous analysis (1190-17145, band 5, 29 January, 1973 and 1191-17204, band 5, 30 January, 1973) were analyzed using the Zeiss 8X and 3X mirror stereoscope. Approximately the same amount of time was spent for the interpretation (about 6 hours) following the landtype association definitions of the Forest Service (Table 2).

The results (Figure 2) indicate wide disparity among the three interpretations. One reason is that the INSTAAR interpreters are less familiar with the area than the Forest Service personnel. Local relief is the key criterion for separating most of the categories, yet the relative relief that the interpreter "sees" may not be correctly calibrated to the actual numerical designations. Using a topographic map in conjunction with the LANDSAT frames may help calibrate the interpreter's sight. However, there is also the problem of what is meant by local relief. This could mean the amount of relief the landtype associations gives to the entire area, or it could relate to dissection relief within the landtype association boundaries. Local relief can be measured over any aerial extent from major drainage to high peaks, or from small tributaries to the top of the interfluve.

Both INSTAAR interpretations followed the method outlined in the previous report (Krebs et al, 1975). The lack of detail relative to the Forest Service map reflects both a lack of ground familiarity and a possible shortcoming of the LANDSAT data. It may also reflect the relative amount of time spent-one day for LANDSAT interpretation as opposed to five days of aerial photo interpretation by the Forest Service. The Forest Service map is not necessarily more accurate. This map was derived from the knowledge and subjective judgements of many different Forest Service personnel. The boundaries reflect a compromise among widely varying opinions within the Forest Service (Brock, 1975, personal communication), rather than a systematic evaluation of the data. It should also be noted that while the two INSTAAR maps are quite dissimilar, the

Table 2. Landtype Association.

Code	Name	Definition
01	Bottom Lands	More than 80% of an area gently sloping and local relief variation ranges from 0-100 feet. Characterized by alluvial deposits. Slope rarely exceed 15%.
05	Rolling uplands	50-80% of an area gently sloping, local relief variation ranges from 300-1000 feet and more than 50% of gentle slope is on upland.
13	Smooth Low Hills	20-50% of an area gently sloping and local relief variation ranges from 100-300 feet.
14	Smooth Mountain Lands	20-50% of an area gently sloping and local relief variation ranges from 300-500 feet.
19	High Hills	Less than 20% of an area gently sloping and local relief variation ranges from 500-1000 feet.
20	Igneous Fluvial (Uneven Mountain Land)	Less than 20% of an area gently sloping and local relief variation ranges from 1000-3000 feet.
22	Canyon - Scarp Lands	Extremely steep (75% plus) cliffs and rims, dominated by rock outcrops and colluvial slopes.
23	Glacial Depositional	Undulating to hilly landforms resulting from glacial deposition. Moraines, tills and outwashes typify the landscape.
24	Rock Outcrops	Exposures of bare rock greater than 80%.
25	Landslide Depositional	Areas of downward sliding or falling of relatively dry mass of earth, rock, or mixture of the two which have become loosened from a hillside by moisture, snow or man.

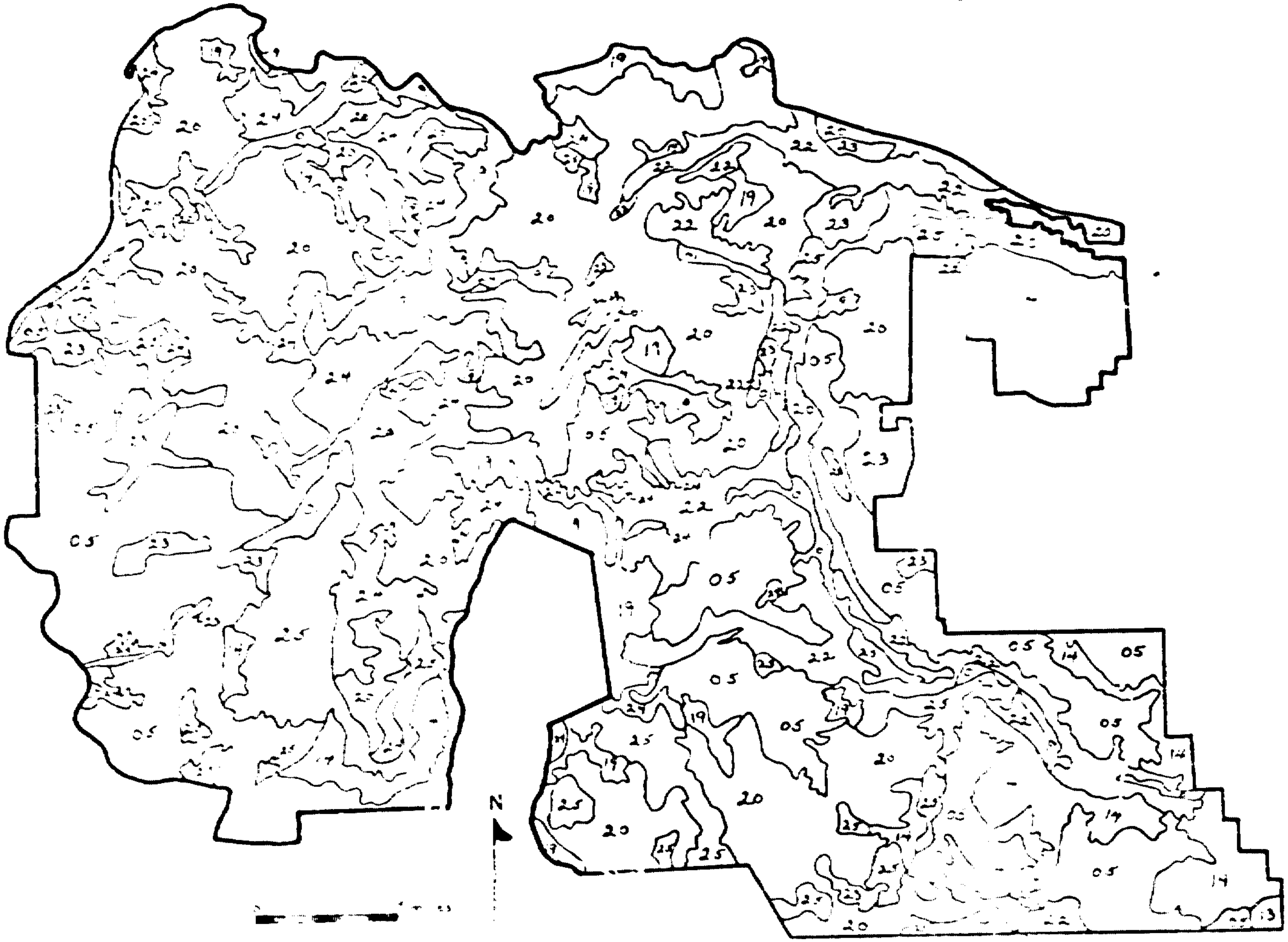
Figure 2. A comparison of the landtype association maps derived by the U.S. Forest Service, Region 2, and two seperate INSTAAR interpreters.

a. U.S. Forest Service, Region 2
b. INSTAAR interpreter 1
c. INSTAAR interpreter 2

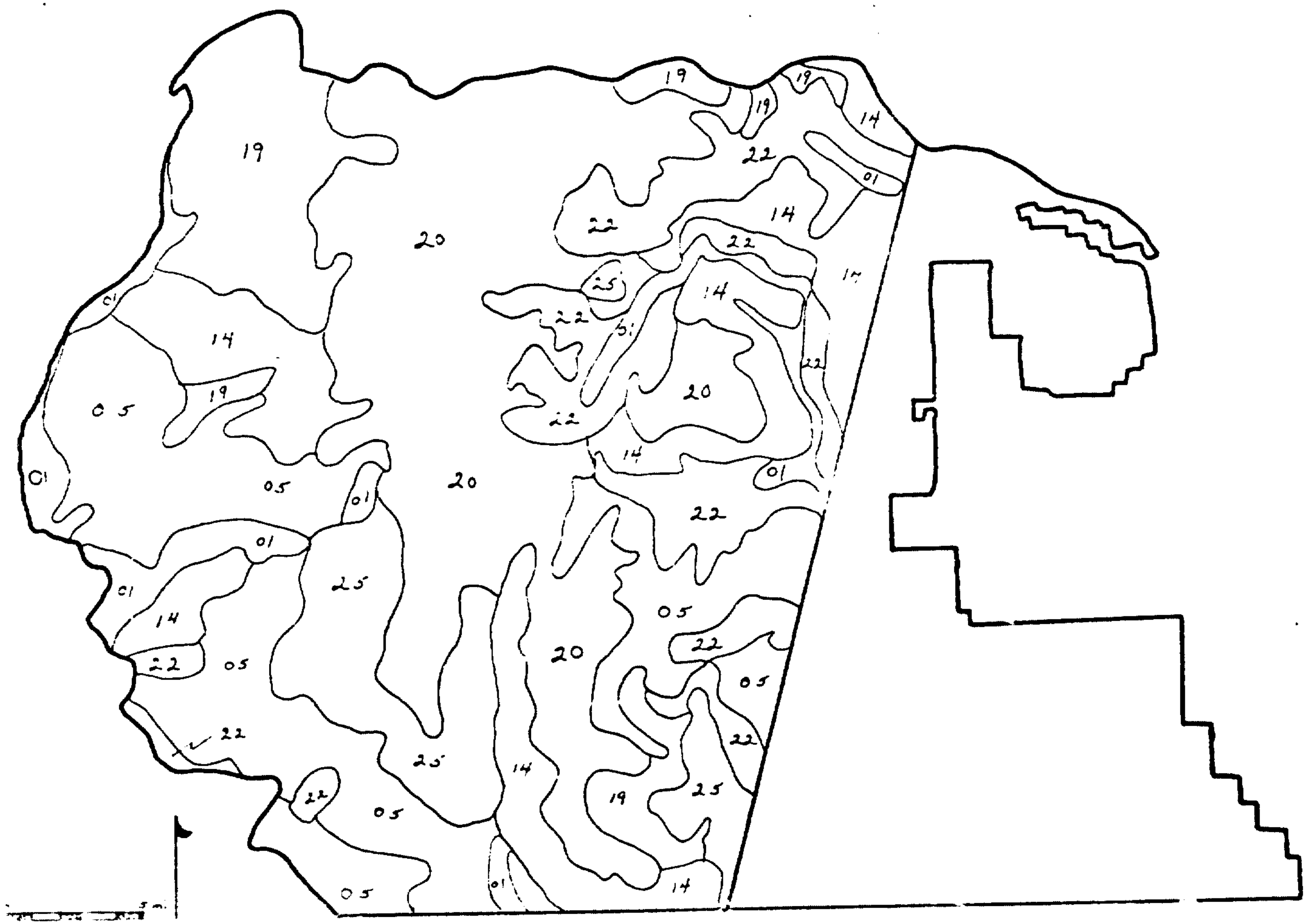
Key for landtype association maps:
(refer to Table 2 for landtype descriptions)

Code	Name
01	Bottom lands
05	Rolling uplands
13	Smooth low hills
14	Smooth mountain lands
19	High hills
20	Igneous fluvial
22	Canyon-scarp lands
23	Glacial depositional
24	Rock outcrops
25	Landslide depositional

A. Landtype associations - Forest Service Interpretation



C. Landtype associations - INSTAAR Interpreter I.



same method was used. This suggests that the classification and definitions developed by the Forest Service need some reworking. The problems are further discussed in Section D.5.

Bibliography.

Krebs, P.V. 1975. Multiple Resource Evaluation of Region 2 U.S. Forest Service Lands Utilizing LANDSAT MSS DATA. Second quarterly report for the period June 1, 1975-August 31, 1975. Prepared for National Aeronautics and Space Administration, Goddard Space Flight Center, 25 pp.

Wertz, W.A. and J.F. Arnold. 1972. Land Systems Inventory. Dept. of Agriculture, U.S Forest Service Intermountain Region, Division of Soil and Water Management, Ogden, Utah, 12 pp.

D.3. Computer-aided techniques by LARS.

Activities of LARS involved the following:

1) Classification of topographic data from DODMA tapes,

2) Maximum likelihood classification of a data set combining topographic data and LANDSAT MSS data,

3) Unsupervised classification which derived 12 spectral classes,

4) Production of sample products for consortium representatives.

A procedure was developed to utilize the topographic data so that grouped areas of similar elevation, slope or aspect characteristics could be displayed in line printer or digital display output format. The source of this data is the DODMA topographic tapes. The information contained on the reformatted data tapes is so detailed that it is difficult to interpret in either output format. For example, aspect is coded in 1^{o} increments, but this is more detailed than the researcher needs. Generalized displays of the aspect, slope, and elevation characteristics of the test site area are more useful. The procedure that has been developed involves the classification of the topographic data into elevation, slope, or aspect increments that can be specified by the U.S. Forest Service. This procedure for grouping the elevation, slope, and aspect data was developed and tested during this reporting period. Examples of the output formats were shown to INSTAAR and U.S Forest Service personnel during the review meeting on October 31, 1975 in Durango, Colorado.

A second aspect of LARS activities involved definition of the analysis procedure to be used in combining topographic data with the multispectral scanner data available from LANDSAT. Since the computer works with data vectors, these vectors can be composed of a combination of spectral data from various wavelength bands, as well as elevation, slope and aspect parameters. The standard maximum likelihood classification technique can be used with such a combination data set. However, in preliminary tests using this standard technique, the classification results did not truly reflect the impact of elevation on the classification performance. When elevation is simply included as another data value in the data vector with the spectral data obtained by LANDSAT, the results did not appear to have as good a classification of cover types as felt possible. Therefore, it is believed that the layered classifier technique instead of the maximum likelihood classification technique, should be used for more effective analysis of the combination of topographic and spectral data. Modifications of the layered classifier software are being made to effectively use this technique for analyzing the combination topographic/spectral data.

The third area of analysis involved a computer classification of the Southern San Juan Mountain Planning Unit using an unsupervised or clustering approach. The Wilkes-Lambda value was used to define the "opti-

mum" number of spectral classes present in the test site. Every fifth line and column of data were used to develop the training statistics for the classification. Twelve spectral classes were defined and used to classify the data. Subjective evaluation of the classification results indicate the classification is not satisfactory. Several informational classes were not accurately mapped using the statistics developed with this clustering analysis procedure. The interpretiation is that a straight clustering approach may work well for amll geographic areas, but is unsatisfactory when applied to large geographic areas. Hopefully, a modified clustering approach will provide better cover type classification. Such modified cluster analysis will be completed during the next quarter.

Several sets of line printer display materials were prepared to familiarize Forest Service personnel with the format and type of output product that can be obtained with computer-aided analysis techniques. At the meeting in Durango a discussion developed concerning the scale and format output that would be most useful to Forest Service personnel. Particular interest was expressed in the classification output using the ECHO classifier (boundry locater). After a satisfactory classification using the modified clustering technique has been achieved for the Southern San Juan Mountain Planning Unit, a classification using the ECHO classifier should be pursued.

To aid in further communications with Forest Service Personnel, INSTAAR was provided with a series of line printer displays. The displays included classifications of slope, aspect, elevation and vegetation for the Vallecito Reservoir area in the Granite Peak test site(SKYLAB contract NAS9-13380). A copy of the un-supervised classification for the entire Southern San Juan Mountains Planning Unit was provided for subjective evaluation by INSTAAR.

D. 4. U.S. Forest Service Planning Effort.

An Ecological Land Unit (ELU) is the basic entity for the Southern San Juan Mountains Planning Unit. An ELU is a unique combination of vegetation and categories of land systems. The vegetation system is at the habitat level of inventory and the land system is at the subsection level of landtype association (Table 3). Sixty-one types of ELU's have been derived for the Southern San Juan Mountains Planning Unit.

These ELU's are then evaluated for management implications by assessing capability, suitability, availability, and compatibility for specific resource uses. Capability is best defined as the potential of a parcel of land to provide a given resource. Suitability is a measure of productivity for that resource and whether or not the resource is renewable. If a parcel of land has been indicated to be capable and suitable for a specific resource, the availability must be determined, i.e. has that parcel of land already been allocated for another use. Every parcel of land is considered for each of the following resources to be managed: forested land-commercial and noncommercial, recreation, habitat, water, and visual resource. Some overlap is expected among these resources and a parcel of land may have several possible resource uses. These resource uses must be compared for compatibility.

The management implications and current management situation are reviewed before defining the management direction with possible alternatives. From this, land allocations and management decisions are made. At this point the land use plan can be formulated. The stepwise and integrated process is summarized in figure 3.

Obviously many of the judgements called for in developing the land use plan require additional detailed data. A set of essential characteristics to make such judgements is being compiled. This is an attempt to reduce the subjectivity in the planning process. Many of these characteristics are topographic or may be inferred from topography.

The use of LANDSAT MSS data to derive a map product of landtype associations and a vegetation classification may provide an avenue for formulation of Ecological Land Units. Currently a manual overlay approach is used to combine and recombine detailed resource data for the needs of the planning process. The digitized topographic data (DODMA topography tapes) have been overlaid on LANDSAT MSS digital data. Upon completion of the vegetation classification by computer-aided analysis an anticipated product will be a results tape. The inclusion of vegetation, elevation, slope aspect, and slope percent on this tape will eliminate the time consuming manual overlay.

The development of a software package for selective recall of combined features from this tape is being discussed with the ADP division of Region 2 offices. This hopefully will provide a tool for long range land use planning and day-to-day use by forest personnel.

TABLE 3. LEVELS OF LAND SYSTEMS INVENTORY (after Wertz and Arnold, 1972)

LEVEL	EXAMPLE	MAPPING SCALE	UNIT SIZE	APPLICATION
Physiographic Province	Southern Rocky Mountains	1:1,000,000	1000's of sq. mi.	Nationwide or broad regional data summary
Section	San Juan Mountains	1:500,000	100's to 1000's of sq. mi.	Broad regional summary. Basic geologic, climatic, vegetative data for design of individual resource inventories.
Subsection	Glaciated Mountains	1:250,000	10's to 100's of sq. mi.	Strategic management direction, broad area planning.
Landtype Association	Uneven Mountian Land	1:60,000 1:20,000	1 to 10's of sq. mi.	Summary of resource information and resource allocation.
Landtype	Ridge	1:20,000	1/10 to 1 sq. mi.	Comprehensive planning, resource plans, development standards, local zoning.
Landtype Phase	-----------	1:20,000 or larger	1/100 to 1/10 sq. mi.	Project development plans
Site	-----------	not generally mapped	acres or less	Detailed on-site action programs.

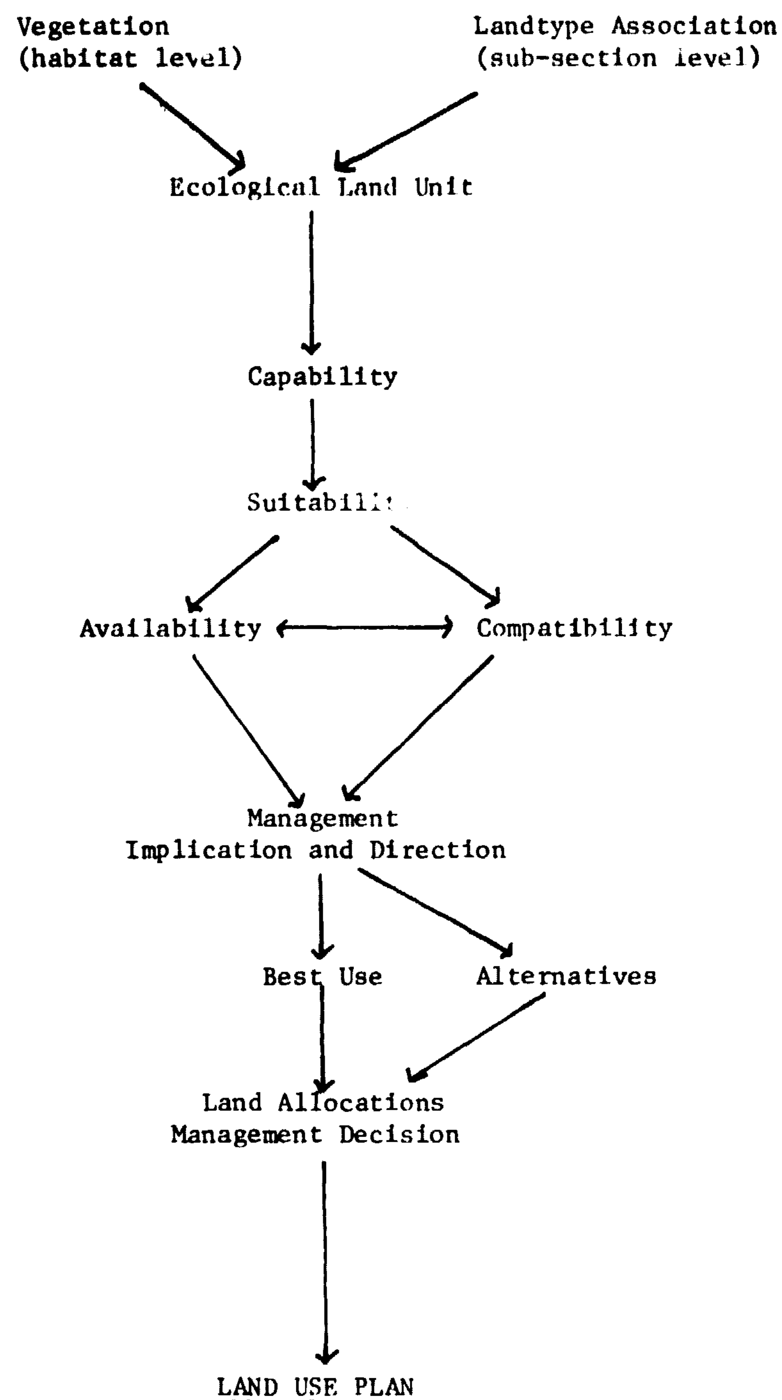


Figure 3. Flow diagram of the stepwise process in developing a land use plan.

D.5. INSTAAR Evaluation of Land Systems Inventory.

As part of further testing of the applicability of LANDSAT data to Forest Service land use planning, it was necessary to first understand the land system classification in use. The Forest Service uses the Land Systems Inventory as outlined by Wertz and Arnold (1972) at all levels of land use planning. The land system is based on a hierarchical breakdown of landtypes from a broad level to more detailed, homogeneous units. Several problems with the Southern San Juan Mountains system became evident, both from a theoretical standpoint (ie., the guidelines of Wertz and Arnold, 1972) and from a practical standpoint (ie., utility and reproducibility). Under the Land Systems Inventory hierarchy the San Juan Mountains are a section of the Southern Rocky Mountain Province, which is further divided into subsections glaciated mountain land and fluvial mountain land (Table 2).

Ideally, each subsection would have unique landtype associations which would be composed of unique landtypes. The landtype association (Table 2) are mostly topographic entities which can occur in both glaciated and fluvial mountain lands. The landtypes (Table 4) are not subdivisions of the landtype association, but rather are different subdivisions of the entire planning unit. For example, sideslopes will be found in smooth low hills, smooth mountain lands, high hills, and several others. Thus, a sideslope is not a more homogeneous and discrete unit of a landtype association but a completely different unit based on a different set of perameters. The landtypes crosscut the landtype associations which in turn crosscut the subsections instead of being subdivisions of the higher units.

The basis of both the landtype associations and landtypes is not consistent within either classification. The inconsistency creates problems in indentification of the units and in interpretation for land use planning decisions, For example, the basis for most of the landtype associations is topographic in nature, ie., slope and local relief (Table 2). Glacial depositional and landslide depositional are genetic classes and will overlap many if not all of the categories. Glacial depositional features, described as "hilly to undulating" and typified by "moraines, tills, and outwashes", could easily be mapped as rolling uplands or bottomland, or mountain land depending on the age of glaciation. Landslides will be concentrated along outcrops of unstable geologic formations, such as the Mancos Shale, but can also be found within any topographic regime. Rock outcrops are included as part of the description of canyon-scarplands but are also mapped separately. Base geologic maps can be used if available. But there seems to be inconsistencies as to the selection of genetic features to be incorporated in the classification.

Similar inconsistencies occur in the present landtype level. The entire planning unit can be mapped as ridge, sideslope or toeslope. However, some small features are arbitrarily subdivided out of these units, and are given relatively more importance by being mapped separately. Alluvial fans are small scale toeslope features; floodplains and benches are small scale bottomland features. The detail in mapping these features is inconsistent with the lack of detail in units such as sideslope. Alpine is a vegetation descriptor, not a landform. Alluvium and till are not

Table 4. Landtype Definitions.

Ridge	A destructional denudational form which is a narrow elongated crest of a hill or mountain.
Flat	A remnant of a structural surface which is a broad and nearly level upland area.
Sideslope	A constructional denudational form which occupies the undifferentiated inclined portions of mountain land, found below the local interfluve and above the fluvial bottomlands. A sideslope is composed of colluvium or colluvial-mantelled bedrock.
Toeslope	A constructional denudational form which is the depositional zone at the base of a hillslope and transitional to lowlands. It is distinguished from sideslope by a discrete change in slope gradient.
Bench	A destructional fluvial-denudational form which is long and narrow, gently inclined and built from constructional fluvial processes.
Floodplain	A constructional fluvial form which is adjacent to a river channel and inundated during annual highwater periods.
Alluvium	A constructional fluvial form which is composed of sand, gravel, cobbles or other transported material. Alluvium includes glacial outwash, or stratified drift that is stream built from glacial meltwater.
Alluvial Fan	A cone-shaped constructional fluvial-denudational form resulting from a tributary of high declivity running into the valley of a stream with less declivity. Alluvial fans include debris fans, or cone-shaped constructional denudational forms.
Landslide	Any constructional denudational form which displays evidence or a history of perceptible unit downward movement of a portion of the land surface.
Till	Any constructional glacial form.
Bare Rock	A miscellaneous landtype which occurs under all geologic formation processes and consists of any surface with more than 90% bare rock.
Alpine	A miscellaneous landtype which is the land surface above the absolute tree limit.

landforms, but deposits which occur in floodplains, benches, and alluvial fans, or moraines. It is inconsistencies such as these which make the system difficult to understand and interpret.

Ideally, any system should be based on the key parameters for the specific land use decisions. In the Southern San Juan Mountains, each landtype association supposedly reflects six essential characteristics which the Forest Service will consider when allocating activities, uses, and resources. The essential characteristics are average precipitation, elevation, range, slope (average and range), relative productivity, mass movement potential, and erosion hazard. When landtypes are combined with two vegetation parameters, cover type and productivity, these form the Ecological Land Units which serve as the base data for planning (see Section D.4). Unfortunately, these characteristics do not really define the landtype associations but merely describe them in a general way after they have been mapped. For example, half of the landtype associations are described by a slope range of 10% to 60%, and six of the ten have an average slope of about 45%. Mass movement potential is variable within each landtype association category depending on slope, and doesn't really define those categories. The characteristics of both landslide depositional and glacial depositional are nearly identical except for origin. The landtypes themselves, which are such an integral part of the ELU's, do not accurately reflect the essential characteristics. After ELU's are defined and mapped, each area must still be examined in detail before management decisions can be made.

Subjectivity is the main reason that the landtype classification in the Southern San Juan Mountains is not systematic. The final classifications are a collection of the subjective judgements of many different Forest Service personnel. Each individual has that "gut feeling" about the nature of each area being mapped and how each area may react to different land uses. The Forest Service knows that certain areas are naturally unsuited for timber harvest. But why? What are the parameters that make an area suitable or unsuitable for a particular land use? Because the limiting parameters for each use or resource have not yet been identified, and because the landtype associations do not reflect a systematic grouping of these parameters, the land use decisions will be based on subjectivity. However, in view of the limited time factor, the landtype associations (and the ecological land units) are the best sources of information the decision makers have. The point here is that defensible management decisions should be based on a systematic evaluation of the limiting parameters for each land use and good base data derived for these parameters. The land systems currently used may be functional to a degree, but needs to be revised as soon as better base data is available.

D.6. Projected Activities.

When the initial vegetation classification by the modified clustering technique used by LARS is completed and evaluated, the INSTAAR personnel will meet with the Region 2 & 3 Forest Service planning team. These meetings will begin the interpretative phase of this project. As LARS develops the terrain mapping and refines the vegetation classification, the INSTAAR and Forest Service personnel will interpret the digital mode of processing and evaluate its usefulness in the system of ELU's and the Forest Service planning efforts. Complete documentation for all mapping categories will be developed as the Forest Service finishes their work with defining ELU's.

Landform mapping from a variety of LANDSAT data products will continue during the next quarter but with slightly different emphasis. The LANDSAT data will be tested to the level of landtypes without restricting the activity to the classification developed earlier. Manipulation of standard products will be emphasized since these are more readily available to the Forest Service and less expensive than most other computer products.

Among planned activities are:

1) evaluation of summer and early winter imagery for drainage pattern analysis and its relation to geologic features,

2) evaluation of stereo pair reversals for mapping bottom land and toe-slope features,

3) establishing a standard set of negative and positive diazo transparencies and evaluating different color and band combination for landform mapping,

4) evaluation of various combinations of different seasons, bands, and positives/negatives for landform mapping,

5) evaluation of various digital display products.

E. Significant Results.

No significant results are identified during this reporting period.

G. Recommendations.

In view of the cost of providing aircraft coverage, every attempt should be made to provide high quality data. The addition of an anti-vignetting filter on the camera systems should be a requisite. If the conditions even remotely indicate an improvised product can be obtained through the use of such a filter, there should be no hesitancy in prescribing its inclusion for the camera system.

Although Ames Flight No. 75-101 was to provide 10% endlap and 10% sidelap as originally designated, 50% or greater endlap was obtained. We are not complaining, but rather praising. Again, to provide high quality data which is useful for most interests, stereo coverage is mandatory. The major cost is in aircraft operation and crew salaries. In comparison the cost of film is nominal. The additional frames necessary to provide stereo coverage should not be a limiting factor if the flight is authorized.

H. Aircraft Data.

The aircraft coverage provided by Flight No. 75-101, Ames Research Center is of immeasurable benefit to this study. The larger scale HR-732 photography covers 40% of the study area. Selection of training areas for computer-aided analysis is being made from this film. Spectral classes from each cluster map are identified as to vegetation cover type from the air photos. This is the initial interpretive phase in the development of a classification utilizing LANDSAT MSS data. The quality of information input at this point directly influences the classification results.

The small scale RC-10 coverage is augmenting the detailed data collected during the field season. A verification of the vegetation cover-type is made from this coverage and boundary modifications are now possible. This combined data set is being used to delineate test fields for an evaluation of the classification derived by computer-aided analysis of LANDSAT MSS data. LANDSAT image interpretation at the landtype association level can be verified using the RC-10 coverage. Those mapping categories not detectable on the LANDSAT imagery can be added using this aircraft coverage. The map framework is provided by LANDSAT image interpretation and special categories are then added from air photo interpretation.

I. Data Use.

Value of data allowed	$1,536
Value of data ordered	$1,292
Value of data received	$1,292

Difficulty was encountered in obtaining information on Ames Research Center Flight No 75-101, flown on 25 June, 1975. Following repeated contact with EROS Data Center and Dr. Price, GSFC, the flight summary report was received. An order was immediately placed for the HR-732 and RC-10 coverages. Edmond Szajna, technical monitor, was notified of the purchase request and account monies were shifted from the CCT account to the aircraft account to cover the cost of $834.00.

As no aircraft data previously was available for the majority of the study area, the acquisition of any coverage was gratefully received. The quality of the frames are quite good. An improvement would have been the use of an anti-vignetting filter on both sensors. The HR-732 coverage is proving to be extremely useful for the detail necessary to select training fields for computer-aided analysis in techniques.

Since the RC-10 coverage has a 55-60% endlap over the mountainous area, photointerpretation for vegetation covertypes is greatly improved. This aircraft data is being used to supplement the detailed field work in providing test fields for evaluation of classification results obtained by computer-aided analysis.

J. Funds Expended.

First Quarter		$14,334
Second Quarter		$10,831
Third Quarter		
Salaries & wages	$8,286	
*Indirect costs, supportive services	$7,434	
Travel & field expenses	$1,718	
Materials	$ 630	
Subtotal	$18,068	$18,068
Subcontract		$61,876
	Total	$105,109

* Includes $4,555 supportive services at Mountain Research Station for the remainder of the contract period to May 20, 1976. These monies are utilized as services provided by an overhead assessment.